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AT? Why? WHEN? HOW? WHERE? WHO?

FOSSILS IN ONTARIO

R. R. H. Lemon

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I keep six honest serving-men
(They taught me all I knew);
Their names are WHAT *and* WHY *and* WHEN
And HOW *and* WHERE *and* WHO.

RUDYARD KIPLING

ROYAL ONTARIO MUSEUM SERIES

WHAT ? WHY ? WHEN ? HOW ? WHERE ? WHO ?

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3 *Walter M. Tovell:* THE NIAGARA ESCARPMENT
4 *R. R. H. Lemon:* FOSSILS IN ONTARIO
5 *W. E. Swinton:* DINOSAURS OF CANADA
6 *L. S. Russell:* THE MASTODON

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WHAT? HOW?
Why? WHERE?
WHEN? WHO?

Fossils in Ontario

by R. R. H. LEMON

HOW are fossils formed?

Fossils are the remains or impressions of animals and plants which lived in prehistoric times. In Ontario we have some of the richest fossil-bearing rocks in the world. We also have some of the very oldest known fossils—traces of primitive plants which lived in the morning of life on earth, 2000 million years ago, when even the most complex form of life consisted of only a single cell. And we have some very recent fossils, such as the bones of mastodons which lived only 6000 years ago when Indians already were hunting in the area. In one small corner near Hudson Bay there may be the remains of dinosaurs, but over the rest of the province the rocks from that era (and therefore also the fossils) have all been eroded away. We have, however, copious records of the period before the dinosaurs, when for hundreds of millions of years Ontario was covered by warm seas which swarmed with a variety of bizarre animals without backbones. It is their remains which are most commonly found in Ontario, and which form the subject matter of this booklet.

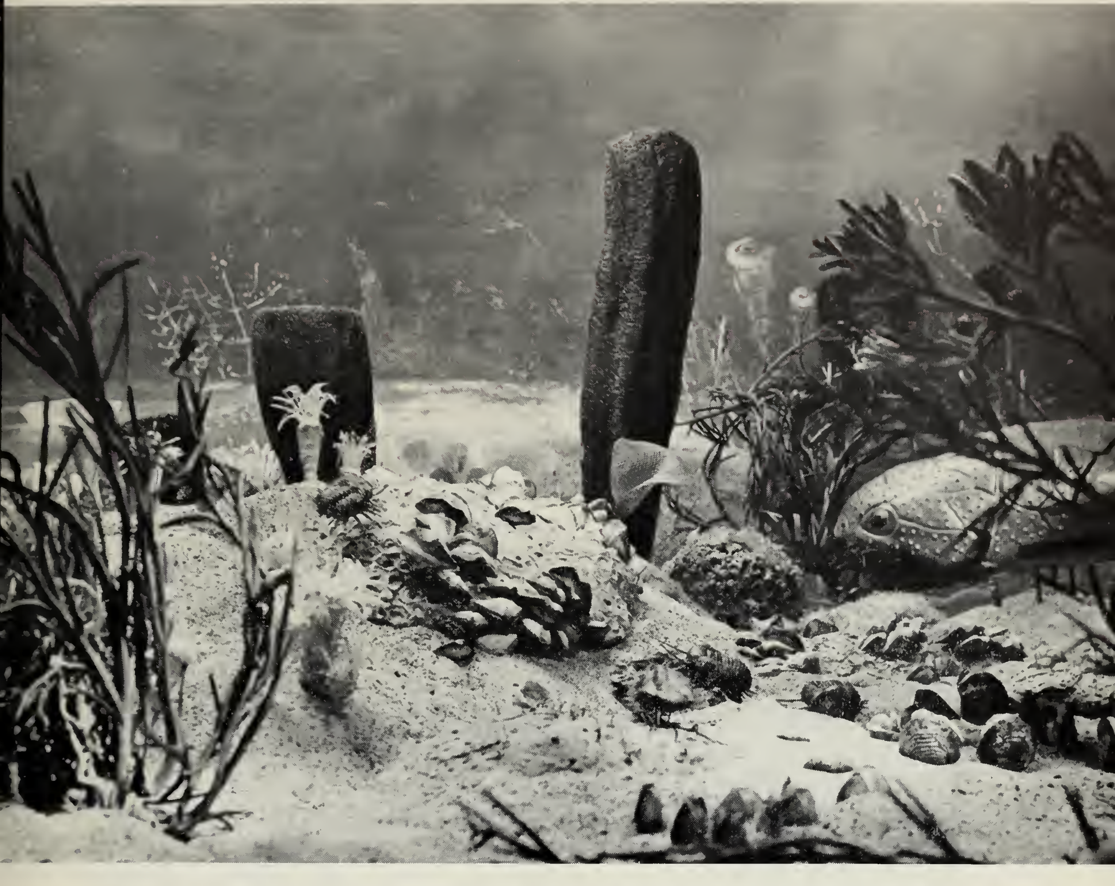
Fossils may be preserved in many different ways, depending upon when and where the animal or plant lived, how it died, and what subsequently happened to the matter entombing it. Some of the processes are quite simple. A mastodon, for example, blunders into a muskeg and drowns; its bones, protected and preserved by the swamp, may lie undisturbed for thousands of years until a bulldozer tears up the land. Or a flying insect is trapped in the sticky resin oozing from a prehistoric pine; the resin hardens into clear amber, preserving every detail of the tiny animal from decay. It is even possible for animals to remain deep-frozen for tens of centuries, embedded in the ancient ice and frozen mud of Alaska and Siberia. One of the most unusual banquets in history was held in St. Petersburg, Russia, at an International Geological Congress at which mammoth steaks were served: one report says the meat was quite edible, though somewhat lacking in flavour!

The most common fossils owe their existence to a much more complex process. In many, the original shell material or skeleton has been replaced completely by another harder and more durable mineral. Let us take one instance. A clam—very much like the ones we eat today—died millions of years ago and its shell, lying on the sea bottom, gradually was buried by a slow rain of sand and mud and organic debris. As the centuries passed the covering layer grew deeper and deeper. Still, water could pass through the sediment and reach the shell. (Obviously, more water would reach the shell if the sediment was coarse-grained, such as gravel or sand, than if it were clay.) In time, the deposits which buried the animal turned into rock. But at the same time, as a result of chemical reactions between the shell material and minerals carried in solution in the water, the shell itself also changed: gradually it dissolved and was replaced, molecule by molecule, by the mineral (usually calcite or silica) deposited out of the water. Thus the original shape and even the finest details of the shell were preserved for the fossil hunter, yet no trace was left of the original material secreted by the clam. It had all been turned into stone.

Often this process happened quite quickly as geological time goes, over perhaps 100,000 years. On the other hand original shell material has been found dating back to the Cretaceous period (see time chart, page 15) and in some shells the mother of pearl has retained its glistening beauty for more than 100 million years.

Unfortunately in the replacement process the shell invariably loses its natural colour, though occasionally faint markings on the fossil suggest the original patterns. Sometimes, on the other hand, the shell assumes a new and alien beauty from the mineral which now forms it, such as the metallic glitter of the iron mineral pyrite or the gemstone colours of chalcedony and jasper. Most likely in their lifetimes the invertebrates of prehistory were no less brightly coloured than those alive today. It seems certain that if a time traveller were to walk along the fringe of some Palaeozoic sea, his eyes would be attracted by many colours among the shells on the beach.

When an animal dies its fleshy parts soon decay and usually only the hard



Warm salt seas once covered the area we now call Ontario. In them flourished a rich variety of creatures. Some appear in this ROM *reconstruction of life in the Devonian period, 400 to 350 million years ago. The tall objects at the centre are sponges. Brachiopods, crinoids, horn corals and trilobites also are evident. Fish, like the armoured specimen at the right, were by this time common. Devonian fossils may be found in the vicinity of Stratford and London.*

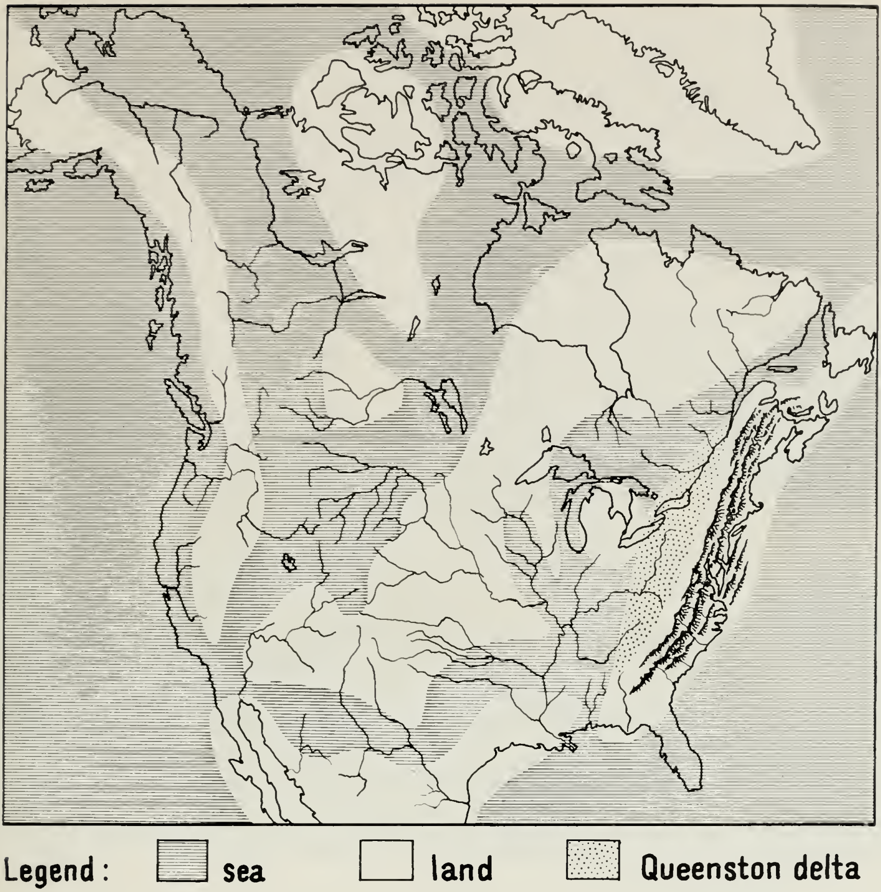
skeleton or shell survives long enough to become a fossil. Yet under exceptional conditions decay may be inhibited until the soft remains have been buried and the surrounding sediment hardened sufficiently to retain an impression. Alternatively, traces of the soft parts may be preserved in shale and other rocks as films of organic carbon resting upon the bedding surface which once was the bottom of a sea. What exceptional conditions make this possible? Decay is largely caused by aerobic bacteria, which like all animals must have oxygen to live: in stagnant pools the oxygen in the water, and particularly in the mud at the bottom, can be so depleted that the bacteria cannot survive. This can happen even in the sea, in enclosed bays or fiords where neither tide nor wind stir up the water sufficiently to replace the oxygen consumed by bottom-living organisms. Under such antiseptic circumstances, the soft parts are preserved for at least a time. Happily for the scientist these same conditions caused mass destruction of life in prehistoric seas, producing a great abundance of fossils of all kinds in fine-grained black shales which occur in rock sequences of all ages.

Fossils may be preserved in any kind of sedimentary rock, not only in ancient sea bottoms, but also in rock formed from the sediment on the beds of lakes and rivers, or even from land features such as sand dunes. But some sedimentary rocks are much more likely to contain fossils than others. Many things can happen even after the special circumstances which record the imprint of a living creature.

The older the rock, the more likely it is to have been metamorphosed, or altered, under great pressure and heat within the earth's crust. In these changes new minerals form, old ones are recrystallized, and invariably any fossils are completely obliterated. Again, rocks are subject to folding or squeezing in the episodes of mountain building which have occurred from time to time through the history of the world. This is another process which destroys, or at least distorts, the fossil record. Then there are the attacks of wind and water. Sedimentary rocks formed in lakes or rivers, or on dry land, are particularly vulnerable and may easily be obliterated as the landscape is sculptured by erosion. This is what happened to the Mesozoic rocks of Ontario. On the other hand, the shallow seas which once bordered ancient continents, and the inland seas which once covered much of today's land mass, often persisted for millions of years, and in them thick sediments of all kinds formed and were protected. Moreover, the rocks laid down in such seas were often very widespread; a single limestone formation may cover tens of thousands of square miles. Yet even deep-lying strata may be lifted to the surface by earth movements and thus exposed to erosion.

WHERE do we find fossils in Ontario?

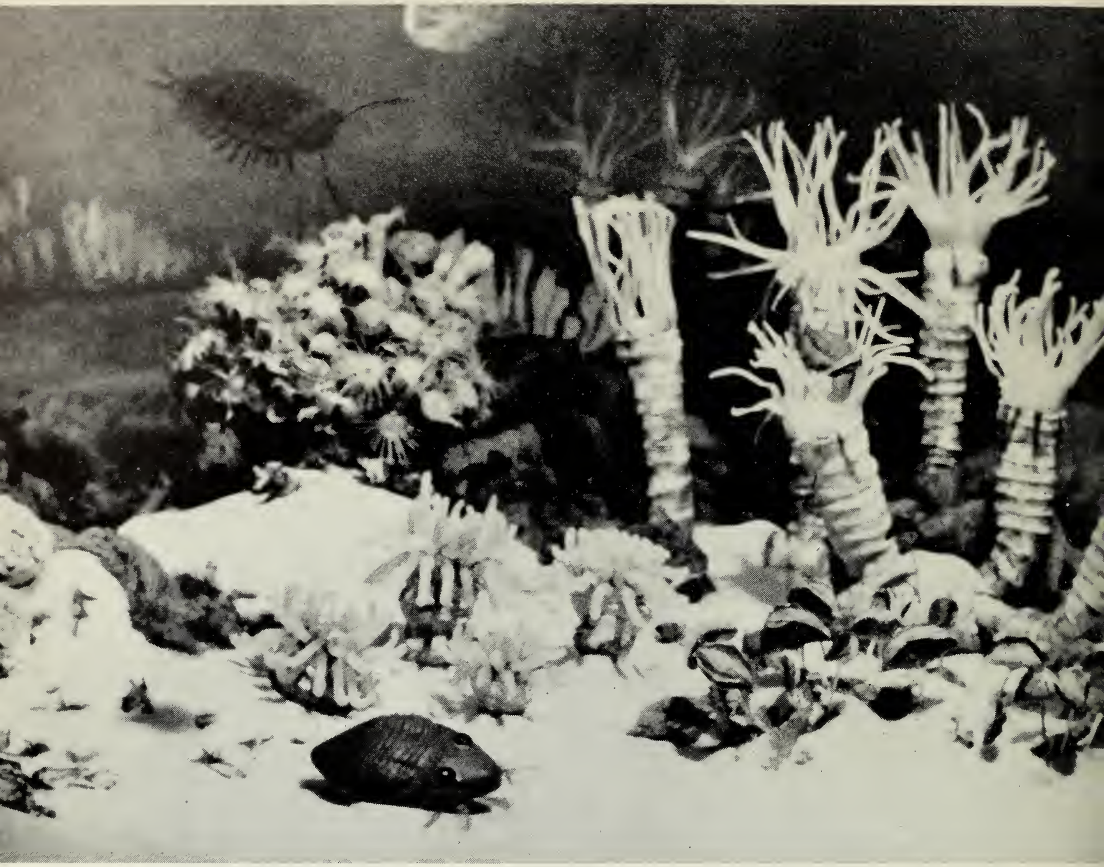
The landscape of southwestern Ontario is new for the most part, as such things go. Large areas of it were formed by glaciers which advanced from the north during the Ice Ages, carrying with them vast quantities of clay, sand, gravel and even boulders which they stripped from the surface in their path. In intervals of warmer climate the glaciers melted, leaving behind their burden. These giant ice fields advanced and retreated during the Pleistocene period, which began some 1,000,000 years ago and lasted until only about 10,000 years ago. Today, in certain sands and gravels laid



Prehistoric seas covered much of what is today the interior of North America. This map shows their extent about 450 million years ago, during Ordovician times. One pocket of dry land was formed by the young Appalachian Mountains and a series of huge deltas which built up to the west of them.

down by run-off from the glaciers, we find fossil shell fish and land snails. Occasionally twigs and leaves and other plant remains turn up, and even more rarely traces of large animals, such as the bones, teeth and tusks of mastodons and mammoths.

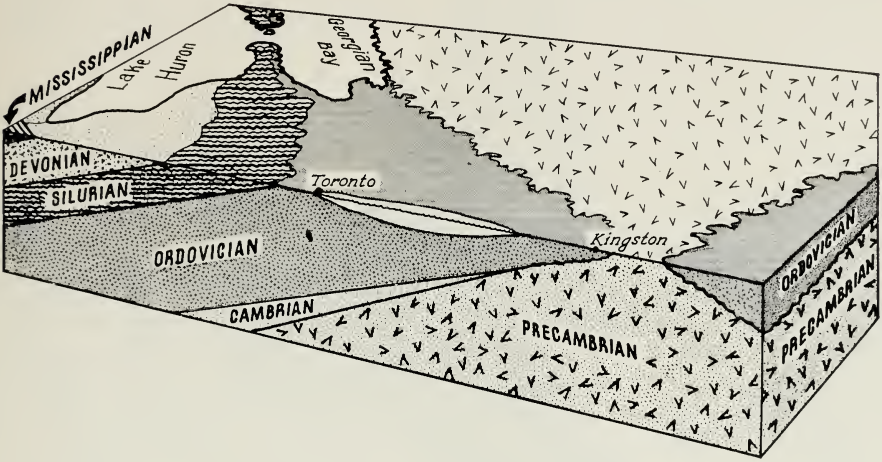
Beneath the glacial deposits, in solid rock, lies the record of a much more remote time. Hundreds of feet of limestones, shales and sandstones were deposited as mud or sand at the bottom of great inland seas which once covered large parts of North America. Ontario was under water during much of the Ordovician, Silurian and Devonian periods (450 to 350 million



In the wavering light beneath the surface of an Ordovician sea, a time-travelling scuba diver might encounter such a scene as this. In the foreground crawls a species of trilobite, Isotelus, *which today is a common Ontario fossil. To the right a group of Rugose corals wave their tentacles from atop their horn-shaped homes. The animals growing on low stalks nearby are brachiopods.*

years ago). During these 110 million years the seas changed constantly, growing larger or shrinking as the land about them fell or rose. It was a slow and complex process: it took millions of years for the shoreline to advance a few hundred miles, and even then the land might rise again, and for a second time be submerged. At river mouths, deltas formed and added other chapters to this story in the rocks. Fortunately, the interior of North America has been largely still over long periods of geologic time. The upthrusts which produced the Appalachian and Rocky Mountain chains on the margins of the continent left the centre largely undisturbed, or at the most faulted, gently tilted or flexed. The record remains for us to read—and the inland seas produced some of the richest fossil-bearing rocks in the world.

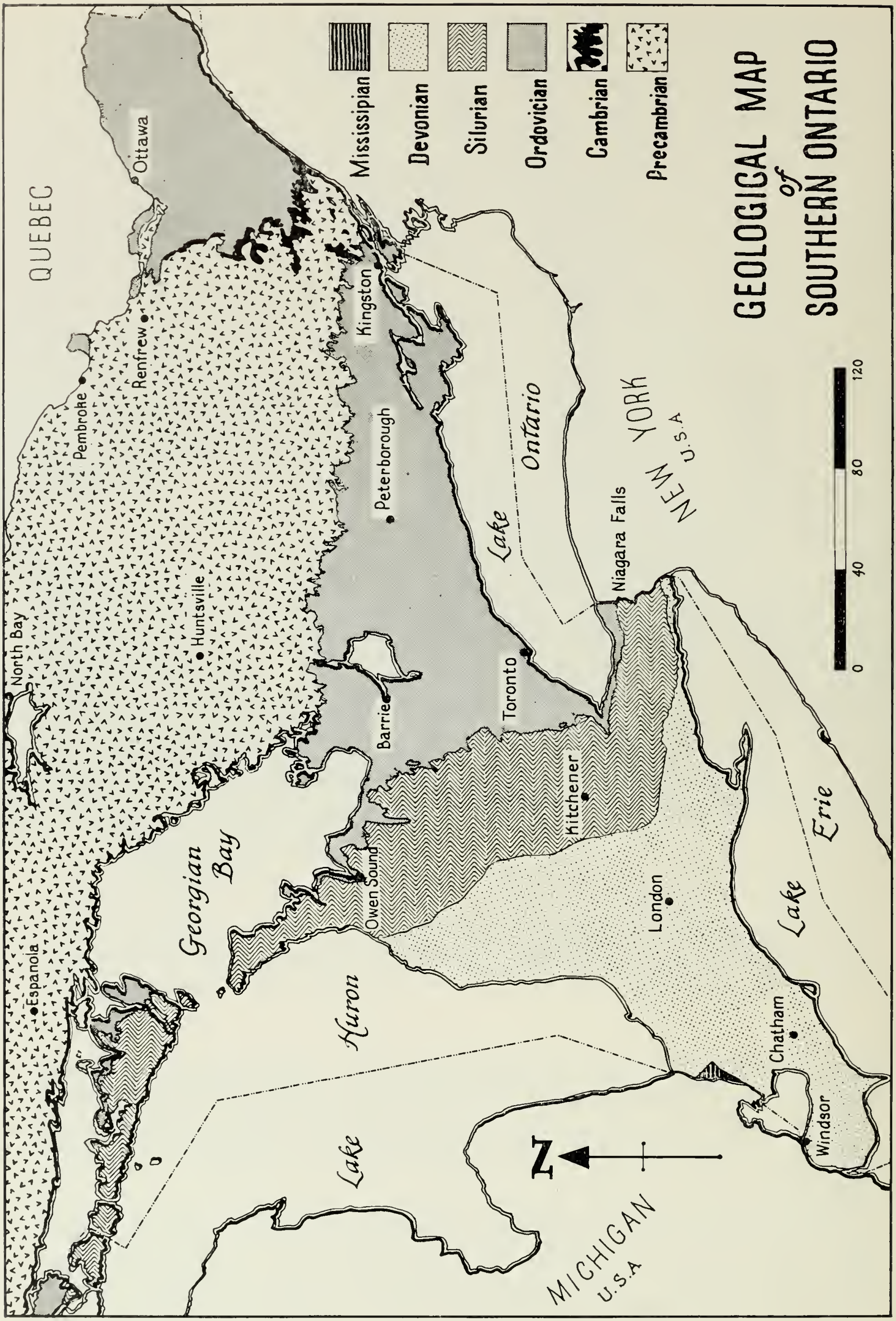
In southern Ontario, limestones, shales and sandstones range in age from Middle Ordovician to earliest Mississippian, with a few patches of Cambrian strata around Kingston. These sedimentary rocks form a series of relatively thin layers above an ancient basement of Precambrian rocks. Some time after their formation a large scale tilting of the whole region caused these layers to dip in a shallow angle towards the southwest. Later still, erosion stripped off the uppermost rocks in the north and northeast regions. As a result the oldest rocks, mostly of Ordovician age, are found at or near the surface to the east and northeast, while the youngest formations of early Mississippian age are confined to a small area in the extreme southwest.



The rock formations of southern Ontario slope gently to the southwest. As a result, fossils can be found from several different periods, progressively more recent from east to west.

If you were to drill below the glacial deposits near Toronto you would encounter only Ordovician and Cambrian rocks before reaching the Precambrian basement; on the Niagara escarpment you would pass through Silurian rocks as well, and further southwest the succession is still more complete.

Wherever streams have cut down through the mantle of glacial drift to expose the sedimentary rocks, there is a potential site for fossil collecting. The richness and variety of specimens of course varies enormously. Many limestones of the Niagara escarpment contain an abundance of brachiopods,



GEOLOGICAL MAP of SOUTHERN ONTARIO

corals, crinoids and other Silurian remains. On Georgian Bay, in the black shales of the Collingwood Ordovician formation, it is possible to find trilobites, brachiopods, crinoids and graptolite fossils in outcrops along the shore.

Fossil hunting is better in natural rocky outcrops than in areas which have been artificially exposed, such as highway cuttings or quarries. The slow weathering of the exposed rock plays a big part in etching the fossils on the surface and in releasing them from the surrounding matrix. On freshly broken rock surfaces fossils are usually very difficult to discover, and even more difficult to extract. This is particularly true of limestones, which are perhaps the most characteristic form of sedimentary rock in Ontario.

You may also find fossils in loose stones lying in river beds and open fields throughout southern Ontario. An hour spent on a farmer's rock pile, cracking open stones of sedimentary origin left behind by the glaciers, can turn up a number of smaller species.

WHEN **did life begin in Ontario?**

Few fossils exist in rocks which date from before the Cambrian period, simply because life forms then were so very primitive. The hard structures capable of preservation were extremely rare, or absent. But the Precambrian basement is not entirely void of evidence of organic life. In a few places in the Grenville limestones there have been found concentrically laminated structures, built up in layers something like cabbages, and measuring up to several feet in diameter. These are thought to represent the work of algae (a primitive plant) capable of secreting a limey framework. Something similar exists today in calcareous algae such as *Lithothamnion*. Numerous different species have been recognized by specialists studying these ancient plants, and the name *Eozoon* was given to one kind found in Ontario. By methods of radioactive dating, using the measured rate of change of uranium to lead, and of potassium to argon, these rocks have been shown to be some 1000 million years old.

Although these fossils are among the oldest direct manifestations of life on earth, similar or more primitive life forms existed alongside *Eozoon*, and for 1000 million years before. In 1965 scientists reported the discovery near Schreiber, Ontario, of fossil algae 2000 million years old, visible only with a microscope. The fossil record becomes more easily discernible, however, at the beginning of the Cambrian period, some 600 million years ago, and through the periods which followed the number, variety and complexity of animals and plants gradually increased.

WHAT fossils are found in Ontario?

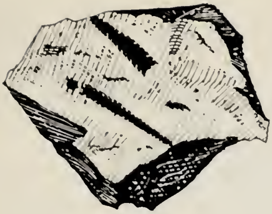
Several thousand fossil species have been found in the province. Some of the most common forms are shown on the following pages. (The name and geological age of each specimen illustrated appears in parentheses after a brief general description.)

GRAPTOLITES are true mystery creatures, without living relations, extinct for nearly 400 million years. They were colonial animals which floated on the ocean surface, forming delicate, often branching, chitinous skeletons, typically no more than ⅛ inch wide and perhaps ½ to 4 inches long. Because they were so fragile, graptolite fossils are usually found only in fine-grained rocks such as shales, deposited in quiet water. On the bedding surfaces they look much like pencil marks. Under a magnifying glass you can see small saw-like serrations along the branches, and under rather high magnification these appear as pores, each of which contained a soft-bodied animal. Graptolites appeared at the close of the Cambrian Period and died out during the Devonian. (*Climacograptus aequalis*: Ordovician)

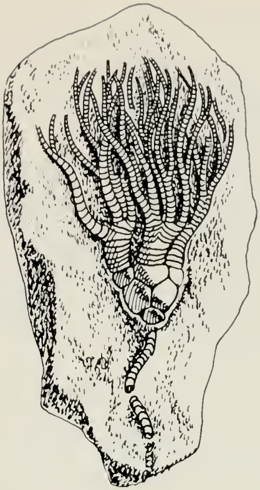
CRINOIDS looked like flowers, but were really animals related to the starfishes and sea urchins. The crinoid's soft body was protected by a series of hard limey plates which formed a small cup-like structure. To this were attached long jointed arms, radiating outwards and upwards, which gathered food. The animal was anchored to the sea bed by a long, flexible jointed stem, made up of small discs connected by muscular tissue. After death the tissue decayed and the discs scattered on the sea bed. Fossil discs (⅛ to ¼ inch in diameter) are extremely common in some limestones. Numerous species still survive. (*Cupulocrinus jewetti*: Ordovician)

TRILOBITES were marine animals with segmented bodies and jointed limbs, related to the crabs, spiders and insects. They appeared in the lower Cambrian, reached their zenith about the middle of the lower Palaeozoic and died out in the Permian. Most trilobite fossils are only an inch or so long, but during the Cambrian and Ordovician, when they were among the dominant life forms, they reached more than 18 inches. In Ontario, Ordovician, Silurian and Devonian rocks contain several fairly common species. (*Isotelus maximus*: Ordovician)

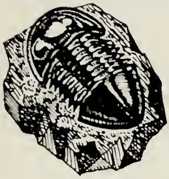
CEPHALOPODS, related to modern squids and cuttlefish, swarmed in the ancient seas. At times they were the dominant invertebrates, and some reached over 4 feet in length. In shape they ranged from straight-shelled species to ones elaborately coiled and ornamented. The straight, cone-shaped variety is perhaps the most common fossil found in the Ordovician limestones of Ontario. Only the wide end of the shell was occupied by the soft-bodied animal which built it: the rest was closed off and divided into a series of chambers by cross walls. When the fossil is broken open these walls often are mistaken for the vertebrae of a fossil fish. (1. *Michelinoceras sp.*: Ordovician. 2. *Plectoceras halli*: Ordovician. 3. Reconstruction of *Michelinoceras sp.*)



Graptolites

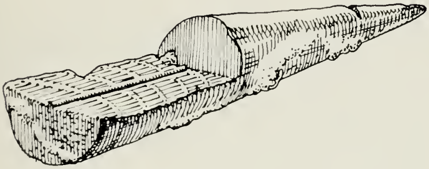


Crinoid



Trilobite

1



Cephalopods

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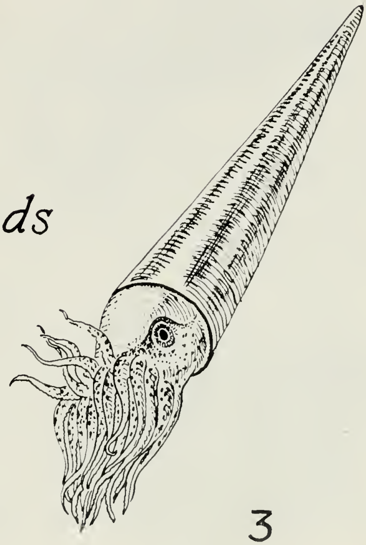

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GASTROPODS (snails) existed as early as the Cambrian Period, and are fairly common in Palaeozoic rocks of Ontario. They lived in both fresh water and marine environments. Pleistocene fossils of freshwater gastropods sometimes can be found in interglacial sands and gravels. (*Fusispira subfusiformis*: Ordovician)

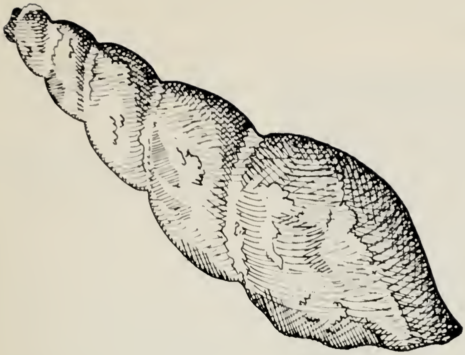
PELECYPODS (clams) are bivalved shellfish. Fossils found in sedimentary rocks throughout the world suggest that during most of their long history (beginning in the Cambrian) they have lived in both fresh and salt water. Since the Mesozoic pelecypods have become increasingly prolific and varied. A few fossil species may be found in Ontario, notably in the Ordovician limestones of the Toronto area and the Silurian Guelph formation. (*Byssonychia radiata*: Ordovician)

BRACHIOPODS superficially resemble clams, but belong to a completely different division of animals. They have an extremely ancient lineage: fossils occur even in Precambrian rocks deposited perhaps 700 million years ago. They were abundant in Palaeozoic seas, and at times were the dominant animal, but have dwindled since the Mesozoic Era. *Lingula*, a small horny brachiopod still found burrowing in mudflats today, is very little different from its ancestors of Ordovician times. (*Spirifier radiatus*: Silurian)

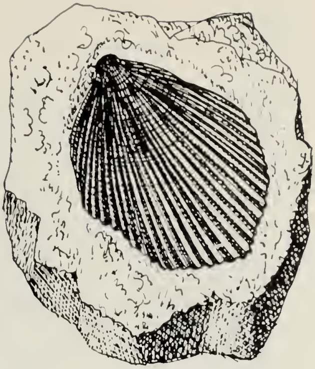
CORALS may be found in many limestones of southwestern Ontario, sometimes in reef masses up to several feet across. Two main groups are represented, Rugose and Tabulate corals. A third major group, which includes all modern reef-forming corals, had not yet evolved when the rocks of Ontario were laid down.

You may find two kinds of Rugose corals. The solitary variety (cup, or horn, corals) are shaped like straight or gently curved cones, within which numerous vertical walls, or septa, radiate from the centre. The walls were formed by in-foldings on the bottom of the soft polyp animal which rested upon this skeleton. Horn corals up to 12 inches long and nearly two inches wide have been found, but are exceptional. Colonial Rugose corals are similar in their internal structure to the solitary variety, but in effect they have been squeezed together in a group—so closely that their skeleton tubes have become roughly pentagonal or hexagonal. The tubes are usually smaller than those of horn corals but contain the same radiating septa.

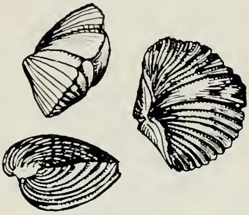
Tabulate (or honeycomb) corals look superficially like colonial Rugose corals, but are very different within. Instead of septa they contain horizontal platforms, or tables, which fill the coral tubes at intervals from top to bottom, rather like floors in a very tall and narrow skyscraper. These can be seen clearly when a colony is broken open. Tabulate corals are never found as solitary individuals and their tubes are invariably smaller than those of colonial Rugose corals. (1. *Heliophyllum halli*: Devonian. 2. *Prismatophyllum williamsi*: Devonian. 3. *Favosites maximus*: Devonian)



Gastropod



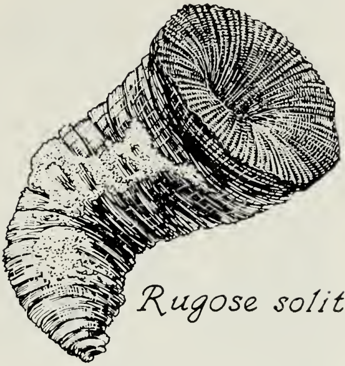
Pelecypod



Brachiopods

Corals

1



Rugose solitary

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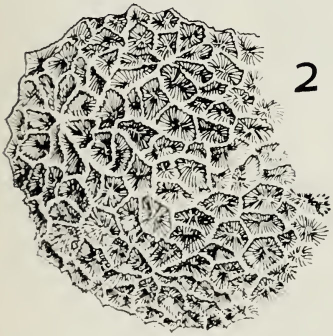

Rugose colonial

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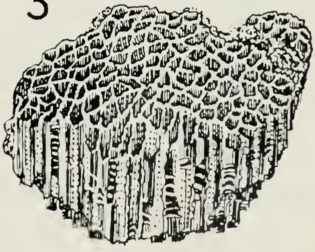


Tabulate

Why aren't these animals alive today?

Nothing in nature is constant. Even the landscape changes, far more than we often realize. Mountains rise and are eroded away, seas dry up, the climate may grow warmer or colder, new forms of vegetation appear and crowd out the old ones. Sometimes the change is violent, as when a volcano erupts in the middle of a cornfield. More often, these transformations take millions and millions of years.

Most animals are suited to live in a particular environment. If it grows too hot or too cold, or their food dies out, or a new species appears which preys upon them, then they may not be able to survive. But if the change is gradual enough, their bodies may adapt, generation by generation, to the new conditions, for the process of change extends to every living creature. Variations, or mutations, are always occurring, and are passed on from one generation to the next. Sometimes they fit the animal better to live in a changing environment. For example, its colour may alter, so that it is better camouflaged from predators, or it may be able to digest a wider variety of plants. Within a particular species, the animals that are better fitted to survive will pass on these changes to their descendants; the animals not so well fitted will gradually disappear; and over tens of thousands of years the whole species will subtly be transformed.

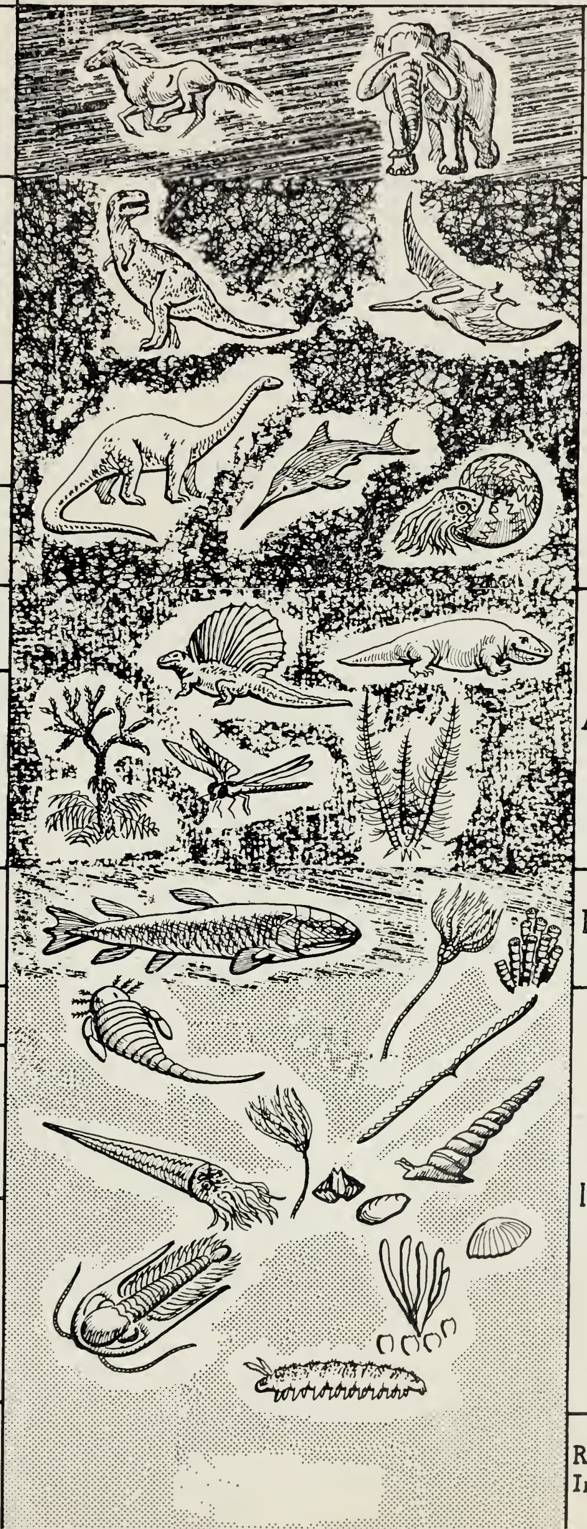
This is a greatly over-simplified explanation of the theory of natural selection, the main factor in evolution, but it suggests some answers to our question. If the environment changes too rapidly for the animals to adapt to the new conditions they will die out. Even if the change is very gradual, it is possible that no favourable mutations will occur. Or if the animals *are* able to adapt, in the process an entirely new species may evolve and the old one disappear. There is one other possibility: that some individuals will be able to find an environment which remains favourable. That is why—300 million years after the last seas dried up in Ontario—a very few so-called living fossils from those days still survive in other oceans of the world.

WHO studies fossils?

The palaeontologist (from the Greek: *palaios*, ancient; *onta*, existing things; *logos*, a discourse) is a scientist who studies the succession of life through the ages, from its earliest beginnings thousands of millions of years ago up to the present. His only clues are the fossil remains, so in part he is a fossil hunter—but that is only the beginning of his work.

In the laboratory his discoveries are cleaned and prepared for detailed study. This may simply involve a small amount of brushing and scraping to remove loose sand or clay. When the fossil is embedded in hard rock,

RECORD of LIFE, THROUGH GEOLOGICAL TIME



ERA	PERIOD	DOMINANT LIFE
CENOZOIC	Cenozoic	*Mammals*
MESOZOIC	Cretaceous	Reptiles Ammonites
	Jurassic	
	Triassic	
PALAEOZOIC	Pennsylvanian	Amphibians
	Mississippian	
	Devonian	Fishes
	Silurian	Invertebrates
	Ordovician	
	Cambrian	
PROTEROZOIC	Precambrian	Rise of Invertebrates
ARCHAEOZOIC		

however, it may mean hours of painstaking drilling, scraping and chipping with the delicate instruments used by dentists and surgeons. In some cases the surrounding rock, especially when it is limestone, may have to be removed by dilute acid which dissolves the matrix without harming the fossil. As in so many things, Nature is sometimes better at such work than man, for rain water is slightly acid due to the presence in it of minute quantities of carbon dioxide from the atmosphere. Thus fossils which have weathered over thousands of years often show details that could never be brought out in any other way.

Even if a fossil cannot be freed from the surrounding rock, it is far from useless. The rock can be cut into thin slices, and when these are etched with acid the internal structure of the fossil can be clearly seen. It is also possible to grind down these slices until they are less than a thousandth of an inch thick, so that they are transparent and their finest details can be studied under a microscope.

Since palaeontology embraces a vast variety of life forms, it is clearly impossible for any one man to study the entire field. Some palaeontologists specialize in the prehistoric animals which had backbones, or even in one kind such as the armoured dinosaurs, or the early mammals, or a particular group of fishes. The invertebrate palaeontologist deals with molluscs, corals, crustaceans and other lower animals, though even here he may specialize in one or two closely related groups. He may for example concentrate on animals like the protozoans which can be seen only with a microscope. Others concentrate on palaeobotany, the rapidly growing study of plant remains—and even of their spores and pollen. Or he may be an applied palaeontologist, using his specialized knowledge to help in the search for oil.

Beside the zoologist who studies living creatures, the palaeontologist faces severe disadvantages: he usually has no direct evidence of what the soft parts of the animal looked like, nor can he observe his subjects' growth and habits. On the other hand, he can accurately reconstruct fossil animals —as they looked in their lifetimes—by studying the remaining hard parts, which may show muscle scars, and by analogy with living relatives. The latter method becomes increasingly dangerous, however, the further he goes back in geological time, for the relationship with living species grows correspondingly more tenuous.

The palaeontologist has one important advantage over the zoologist. He has access to a whole new dimension—time. By studying the fossil faunas through successively younger layers of rock, he is often able to piece together the life history not of an individual, but of a whole race of animals. He can often discern the earliest beginnings of a group and follow its gradual evolutionary changes over millions of years, seeing how one particular species evolved and gave rise to others. Thus he can trace the various branches and stems of the tree of life.

SUGGESTED READING

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